Construction

Engineering and Construction Brief Report

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SOLAR DECATHLON EUROPE 2010

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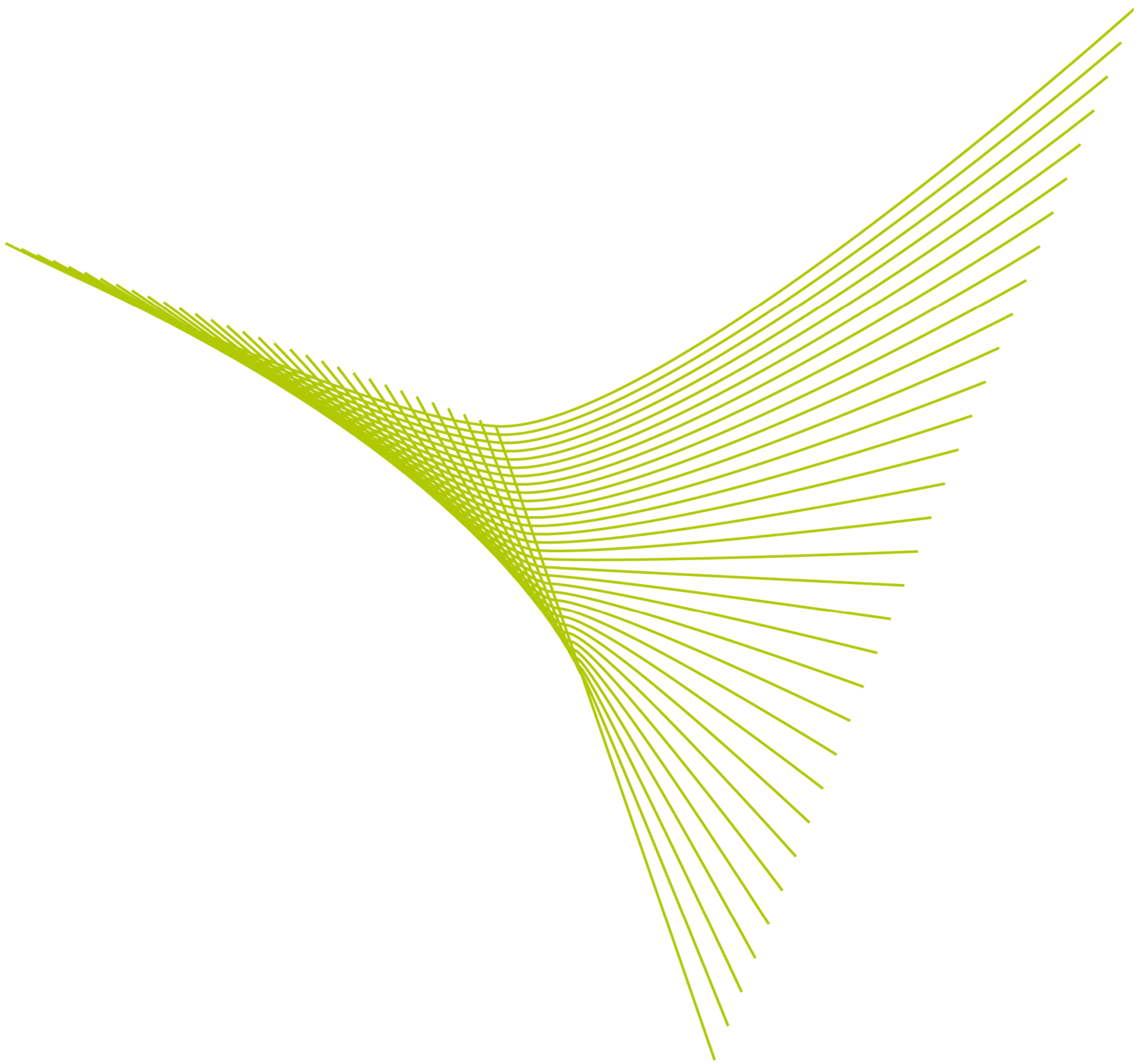

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1. Constructive design of the house

The main requirements for the construction of our house are the following:

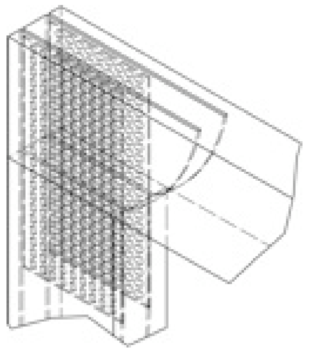
Internal
- Architecture
  - modular construction
  - glass facade in the south
- Sustainability
  - sustainable materials
- Industrialization
  - 90% prefabrication
  - defined transport dimensions

External
- Rules & Regulations
  - above-ground foundation
  - fast mounting
  - defined footprint
  - repeated mounting and dismantling

The architectural requirements suggests a frame construction as the ideal construction approach. Because wood is indisputably the most sustainable of all available construction materials, it was clear to us that this is the only material we want to use for the main structure. The other requirements could be met by relying on the following intelligent detail solutions:

Construction of individual modules

Main supporting structure: frame girders (GI 28h) with innovative, rigid corner joints, the „wood-steel-bond" (HSK)



3D-renderings of the rigid corner joints

description: Upper chord (w/h=80mm/ 160mm) and floor beams (w/h=80mm/ 120mm) are glued to the poles (w/h= 80mm/ 160mm) by using 2 slitted perforated plates (t=2,5mm).
functionality: The 2K polyurethane adhesive forms plastic dowels inside the hole of the perforated plates.
=> force transmission: metal-adhesive: mechanical interlocking; woodadhesive: adhesion
advantages: allows small superstructures, makes transport easier, minimizes the demand for timber trough:
- reduction of panel moments => less deflection
- higher stiffness particularly during transport
- smaller gross wood cross-section of only 10% (for comparison: dowel connectors as classic rigid wooden connection 50%)

Roof and floor construction: Plate girders (GI 28h, Kerto) with main-secondarybeam-connection (Ricon)
description: Roof and ceiling joists (w/ h=80mm/120mm) are mounted between the frame girders, which form the end pieces of the modules, by using Ricon connectors. Then, a plate by Kerto (t_{roof}=33mm/t_{floor}=21mm) is attached by means of a screw-pressure bond.
functionality: The screws create the necessary pressing power, which does not exceed the admissible limit of the bond line of 0,3mm. The 1K polyurethane adhesive creates a rigid connection between beams and plate.
advantage: allows small superstructures through:
- enhancing rigidity and moment of inertia at the same static height (as compared to the classic wooden beam) => less deflection, higher bearing capacity

Glass facade: three-paned insulation glass
description: A special feature of the facade is that unlike in the conventional method it is not realized in the form of a fronted mullion-transom-facade, but the load of the big glass panes (approx. 2,8m/ 2,8m) is transferred directly into the support structure of the house.

advantage: less consumption of material, high degree of prefabrication, allows small superstructures

Connection of the modules

description: The modules are interconnected with 7 Knapp Walco V80 connectors and 10 Walco D connectors.
functionality: After they have been precisely aligned, the modules are simply hooked into each other. The forces at the edges of the modules are transferred via the Walco V80 connectors. Thus, the horizontal forces can be transferred via the bottom and cover panel into the wall panels and finally through the foundation into the ground. The Walco D connectors have been designed especially for our house and ensure an even circumferential joint. They are flexible in the horizontal direction.
advantages: fast mounting, high degree of prefabrication

Foundation

description: The foundation of our house will consist of 23 individual foundations made of cross-laminated-timber. Our zigzag facade, which in its retracted state vanishes below the terrace, defines the elevation height (1,0m+x) necessary for our house.
functionality: A horizontal cross-laminated-timber board (a/b=750mm/750mm, t=97mm) ensures the load transfer into the ground. The elevation is facilitated through vertical a cross-laminated-timber board (a/ b=750mm/400mm+x, t=97mm), which is supported via 2 supporting boards. The level can be adjusted on the construction site by simply cutting the vertical cross-laminated-timber boards to size.
advantages: fast mounting, economically efficient and sustainable because waste materials from the industry are used.

Mounting

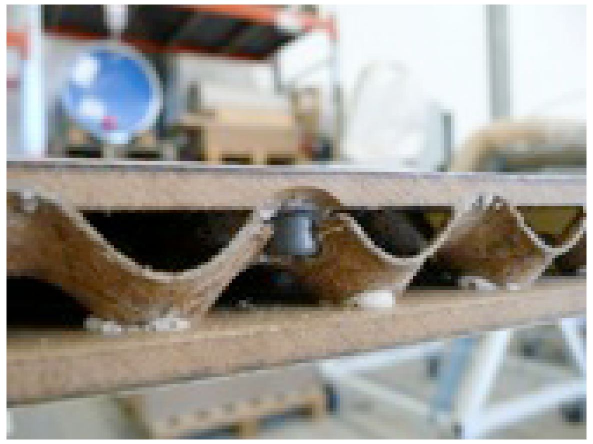
description: As all pieces of built-in furniture and sanitary installations are already integrated in the modules, the heaviest module weights 7,2 tons, even despite the use of light-weight materials . An especially designed suspension device has been developed, with the help of which it can be ensured that when the modules are lifted the load transfer occurs form below.
functionality: Steel girders (IPE 80), which are supported in an articulate manner, are attached to the lower steel girders (hollow section w/h=100mm/200mm, d=10mm) via an adapter piece. Above the modules, a steel girder (HEA 100) is clamped, which keeps the construction at a distance in longitudinal direction. Mounting in transverse direction is facilitated through a wooden beam (Gl28h, w/ h=100mm/200mm). The static system of the actual house construction is not changed.
advantages: fast and safe mounting, high degree of prefabrication

The first module is placed on the foundations for test assembly.

Interior fittings

For all applications in the area of interior fittings/furniture the lightweight building board lisocore® by lightweight solutions® will be used.
Compared to conventional chipboards it results in 20% less weight while at the same time providing better stiffness. As this board has not been used in cabinetry so far, a new development was necessary to facilitate fixing of the fittings. For this purpose, blind rivets normally used in the metal and plastics industry have been deployed.
We had to come up with special constructive solutions for almost all multifunctional ele-

ments in the interior due to the limited footprint and its optimum use. For the guides of the sliding panel, for example, a special metal substructure has been developed, so that an eccentric suspension could be realized, which runs only along the ceiling and guides the sliding panels that are cantilevering at the side. Pressure beams are integrated in this substructure, as well. In the resting state they lock the wall without requiring any bars in the floor or ceiling.
The wall and the sliding panels can be moved over linear guide systems, which are normally used in machine construction. They are mounted so that they are almost clearance-free and absorb the resulting eccentricity and leverage. The power supply and other necessary supply lines are provided trouble-free via an E chain, which, too, is used in the field of machine construction.
The challenge of variably suspending a pendant light with a rod antenna on the ceiling, without having to use a ladder or tools, inspired the idea of a magnetic plug connection. The invention is a plug connection with magnetic traction for lights, ceiling loudspeakers etc. The jack plug is lead through a toroidal magnet.
As soon as non-magnetic plugs are inserted, the magnet draws up the modified bushing of the jack plug. A magnetic traction is created, which in the case of the prototype supports approximately 60N.



Blind rivets for fixing the fittings.

Facade

Aim of the facade construction:
Our vision was to construct a three-dimensional, sun position-based building envelope and to develop an innovative and slidable facade based on a conventional system, an that with small effort.
Starting materials: standard jag belt guide system as available on the market
Modification: increase of motor torque and tooth belt reinforcement considering the weight of the facade development of curved aluminium facade elements in the Z profile, which facilitate the kinematic process adjustment to movements with slide bearings and guide optimization
Result: low-maintenance, temperature-independent and lubricant-free facade system with maximal stability up to wind force 5

Student at the production of the „Zig-Zag“ facade.

2. The building‘s envelope

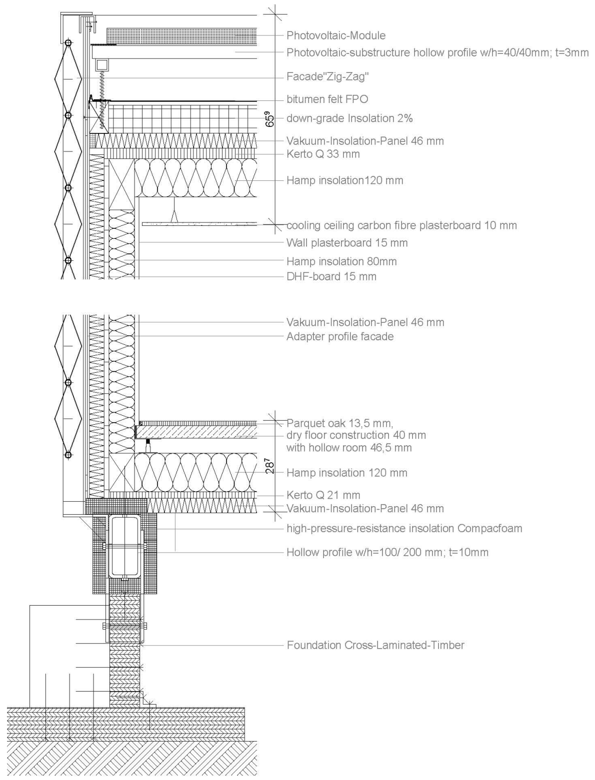
The envelope of our plus energy house comprises highly-efficient materials. They meet even higher requirements than assumed for a passive house.
Because of the small footprint of 74 m² the house is cased with a space-saving vacuum insulation panel (VIP) without thermal bridges. The superstructures of the opaque wall surfaces, ceiling and floor reach a U-value of <0,10 W/m²K. [image: details] The glass panes have a heat transfer coefficient of 0,56 W/m²K - in the installed state 0,78 W/m²K.

The evaluated sound insulation rate (RW,R) of the facade, calculated according to DIN 4109 supplement 1, is 36dB. This value could be reached through an asymmetrical pane structure with sound insulation foil integrated in composite safety glass (VSG). In the interior, the materials as well as the surface design have been chosen with view to the reverberation period of 0,57 sec (at a frequency of 1000 Hz, calculated according to DIN EN 12354-6).

The entrance area includes fixed glazing with LCD technology. For switching, the LCD crystals are rectified with 60 VAC. When there is no current, the glass is translucent. As soon as electricity is supplied, the glass becomes transparent within 100 msec.

At the northern terrace sliding-folding-doors are installed. The interior door system forms the thermal envelope and is realized in the form of 3-pane safety insulating glass. The exterior system, which consists of two panes of safety insulating glass, closes off the winter garden flush with the building envelope, so that the winter garden serves as a climate buffer. The construction extends over a corner and does not require a support. Both systems are supported on the floor, so that permanent subsidence or movements during transport are optimally avoided. The measured n-50 value is 0,5 1/h. The combination of circumferential double seal and barrier-free threshold of the sliding-folding-doors represents a new development.

The outer building envelope consists of a stationary facade and a moveable sun protection. These two systems have been developed, designed and built by students of the University of Rosenheim.



Detail section.

3. Systems of the house

Principles of the energy concept

After the building envelope, geometry and orientation have been optimized, the requirement of transferring the remaining loads through an efficient and sustainable building services system and thus guaranteeing that the comfort criteria are complied with still remains.
The energy concept is based on radiation cooling and a latent heat accumulator, which is equipped with phase chance material (PCM). These two passive systems are supported by a brine/water compression heat pump, which supplies hot drinking water and covers occurring peak loads. These peak loads are transferred with the help of two air-based components, the PCM channel and the living space ventilation, that is provided by means

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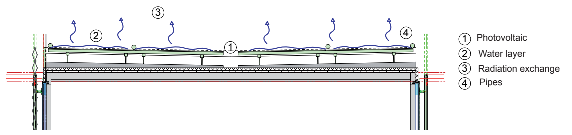
of the heat pump. To cover the low base load in the building, a panel cooling system in the form of a cooling/heating ceiling is used, which is fed by the radiation cooling. The measuring, control and regulation technology of the building services is realized with the help of a DDC (digital direct control).

Radiation cooling

The passive principle of radiation cooling is based on the physical effect, that a warm surface, which is sprinkled with water, releases energy to the colder environment through convection, radiation exchange with the night sky and evaporation processes (adiabatic cooling). Because the radiation temperature of the atmosphere (sky temperature) is often considerably below the external air temperature, a fluid to be cooled can thus be cooled down below air temperature.
This is realized by sprinkling the photovoltaics system, that is installed on the roof, at nighttime. Here, the cooled water having a temperature of 16 ° - 18° C is collected in the drainage system and stored in a 2000 liter cistern. During nighttime operation the cooling capacity of the radiation cooling lies at approximately 1,0 kW – 1,5 kW. Here, the pump power for wetting the roof surface is approximately 0,2 kW, and the circulation pump of the cooling ceiling circulation has a power of approximately 15 watt. Thus, a continuous cooling of the building is ensured during daytime with minimal use of auxiliary energies.



Schematic scetch of the radiation cooling

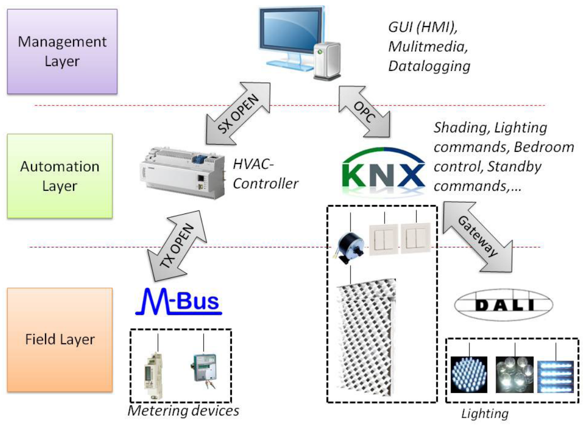
PCM channel

Phase chance materials are materials, in which the storing of heat of fusion is technically utilized. Thermal energy is released or absorbed, as soon as a phase change from liquid to solid, or the other way around, occurs in the substance. This is realized through an air duct below the house, which is connected to the PCM storage. In recirculated-air operation, warm air flows through the PCM storage, giving off energy to the PCM and thus cooling down. In preliminary tests at the university, a temperature difference of 10 K was reached (34 °C / 24 °C) at a volume flow of 600 m3/h and a cooling capacity of up to 1,9 kW was measured. Here, the electrical power consumption of the fan was 180 watt. If the necessary nighttime recooling of the PCM through outside air operation is considered, during which the energy absorbed at daytime is released again, a coefficient of performance (COP) of approximately 6 can be assumed.

Photo showing the inside of the PCM-Channel

Building Automation and Control System

By using different automation systems and making maximal use of the advantages of every individual system, we are aiming at achieving optimal results. For living space automation a KNX system is deployed. In the special field of lighting technology, a DALI system is used, which is connected to the KNX bus. In this way, a wide spectrum of illumination possibilities can be realized. Steering and regulation of the entire HVAC technology (radiation cooling, PCM, heat pump, ventilation system, heat/cool distribution), as well as the entire measurement data acquisition is carried out by a DDC system (digital direct control) by Siemens Building Technologies. In this way, a permanent and centralized access to the entire HVAC technology is facilitated. By optimizing the regulation strategies for HVAC technology, which have been developed within the framework of a diploma thesis, maximal energy efficiency of the entire air conditioning is achieved. Energy data are acquired by using a electricity and heat meter and transferred via a so-called M bus (metering bus).
Within the framework of three diploma theses a user interface (GUI = graphical user interface) was programmed, which is operated on a touch-panel. This GUI facilitates central access to the automation and control system and combines functions of room automation, climate regulation, lighting control, multimedia applications as well as other features.



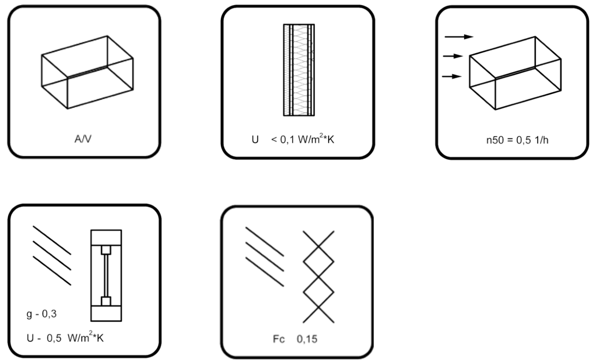
Overview of the Building Automation and Control System

4. Energy

In order to realize a plus energy house with maximum comfort there are three essential optimizationaspects to be considered:
a) building envelope – compact shape of the building, orientation, geometry, reduction of transmission
through structural components, windage losses as well as intelligent use of opaque or transparent
wall structures
b) building services – use of passive or highly-efficient components
c) power generation – integration of energy-generating systems, e.g. photovoltaics or solar thermics

Impact of the simulation on the design

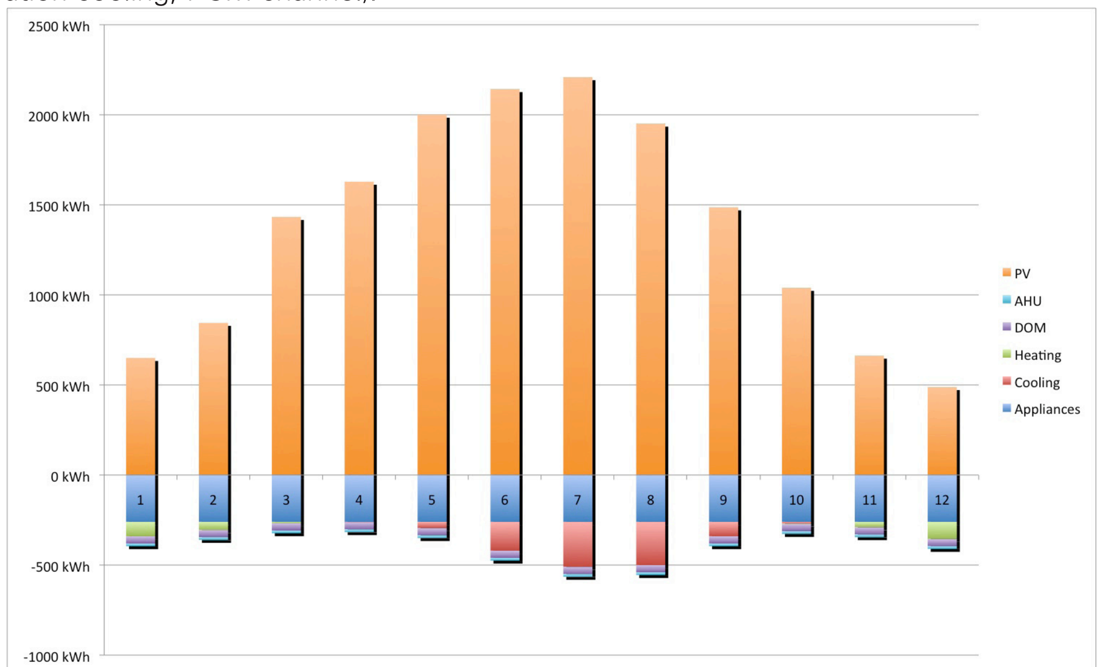
The following parts of the building envelope have been modified during the ongoing design process based on simulation results. The floor plan has been optimized from a Z-shape to a rectangular geometry, so that an enhanced surface-volume-ratio could be achieved. The structural shell has been oriented towards the south, because in this way the gains of the photovoltaics system could be increased. The transparent walls in the east and west have been turned into opaque wall surfaces to avoid excessive heat loads. To facilitate the use of the house in different climate zones, the south façade has been completely made of glass. In this way passive solar gains can also be used in northern regions. In southern locations (Madrid) the solar loads are transferred through the interaction of an especially developed jagged facade, solar protection glazing and the high position of the sun. The surface of the photovoltaics system installed on the roof has been enlarged from 50 m2 to 69 m2 to maximize generation of the required energy. Calculation results showed that when instead of mineral fibers vacuum insulation panels are used as damping material, enhanced transmission properties can be achieved. Based on these and further analyses it was possible to optimize the building envelope until considerably below passive house level.



Symbols of building performance

Determination of loads and gains

In the early stages of the design process rough decisions about the window surfaces, orientation of the building and shading have been made with the help of the PHPP (passive house projecting package). For more detailed analyses thermic simulations have been carried out with the programs IDA – ICE and ESP-r.
The resulting cooling and heat loads could be determined, also taking into account comfort limits.
Consumptions and loads for household appliances, light and building automation have been simulated by using test setups. Balances regarded over the period of one year show that under real conditions like the competition conditions in the location Madrid the building generates four times as much energy as is required for its operation. This can be achieved through a highly efficient photovoltaics system (12,6 kWp – 16400 kWh/a) as well as through the reduction of the cooling load (that constitutes a major consumption factor) to 17 kWh/a*m2, which is covered by passive/hybrid installation components (radiation cooling, PCM channel).



Energy-Balance (location Madrid)

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